Automatic Segmentation of the Choroid in EDI-OCT Images using Clustering and Deep Learning

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Purpose

- To propose and evaluate a new method based on clustering and deep learning for fast and accurate segmentation of the choroid in enhanced depth imaging (EDI) optical coherence tomography (OCT) images.

Background

- Change in choroidal structure has been shown to be correlated with several chorioretinal diseases[1, 2]
- EDI OCT allows us to study the choroid and enables us to measure the thickness of choroid[3]
- Manual annotation is the mainstay for choroidal thickness measurement which is laborious and subject to human error
- There is a high demand for developing a technique for automated choroidal segmentation

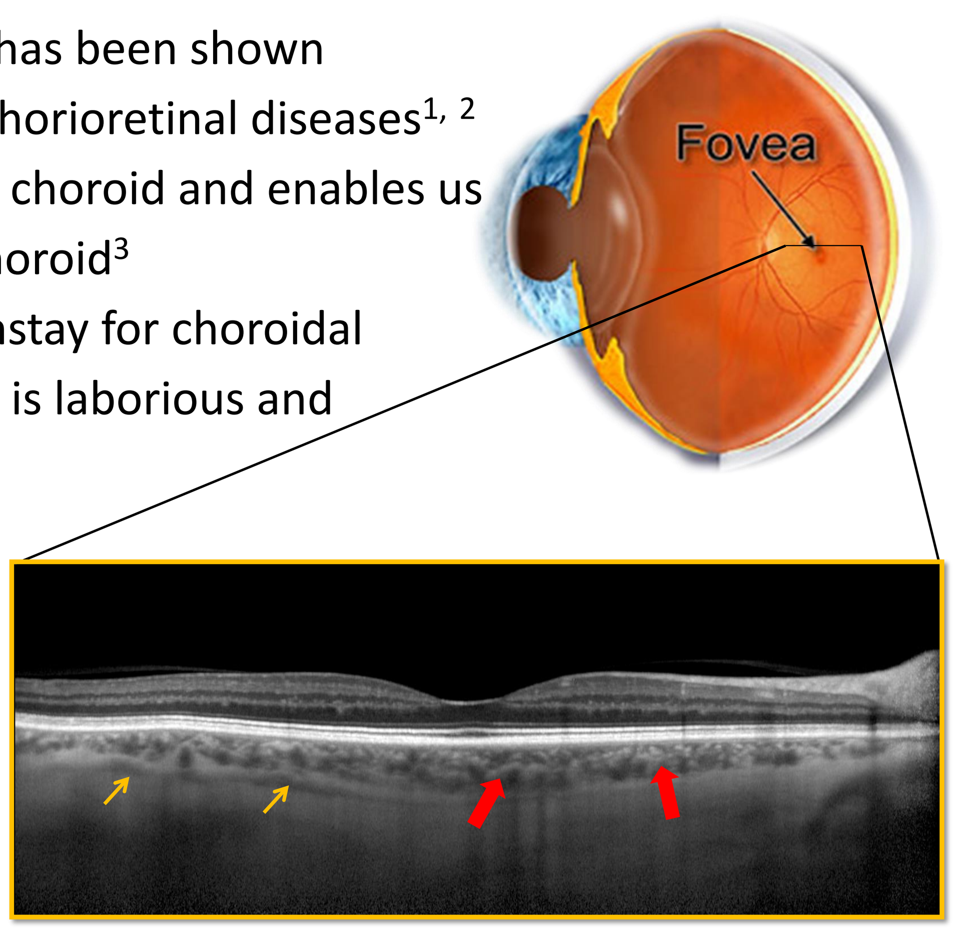


Figure 1: Choroidal structures, Red arrows indicate large choroidal vessels, Yellow arrows indicate the presumed suprachoroidal space.

Methods

- A dataset of 169 retinal EDI-OCT B-scan images acquired using the Heidelberg Spectralis (Heidelberg Engineering, Germany) was used
- 135 images (80%) were randomly chosen for training, of which 34 (25%) were randomly chosen for validation. The remaining 34 images (20%) were used for independent testing.
- Following graph-search segmentation of the inner choroidal surface, we develop a **two-stage** method for segmenting the outer choroidal surface.

1. **Super-pixel clustering and patch extraction:**
   We cluster image pixels into super-pixels based on distance and intensity similarity, then define patches centred on the super-pixel centres, considering several patch sizes were considered for CNN training.
2. **Patch labelling with Convolutional Neural Networks (CNN):**
   Using the patches, we train a CNN comprising two convolutional layers each followed by a sub-sampling layer with rectified linear unit as activation, a fully connected layer, and two dropout layers with ratio 0.5. The output layer classifies the patches as choroid or non-choroid. We augment the data by randomly flipping the patches horizontally and train the network for 300 epochs.

- The accuracy of our proposed technique was evaluated on the test images against reference manual annotations using Matlab software (Mathworks, USA) using accuracy and the Dice Similarity Coefficient (DSC)

Methods (cont.)

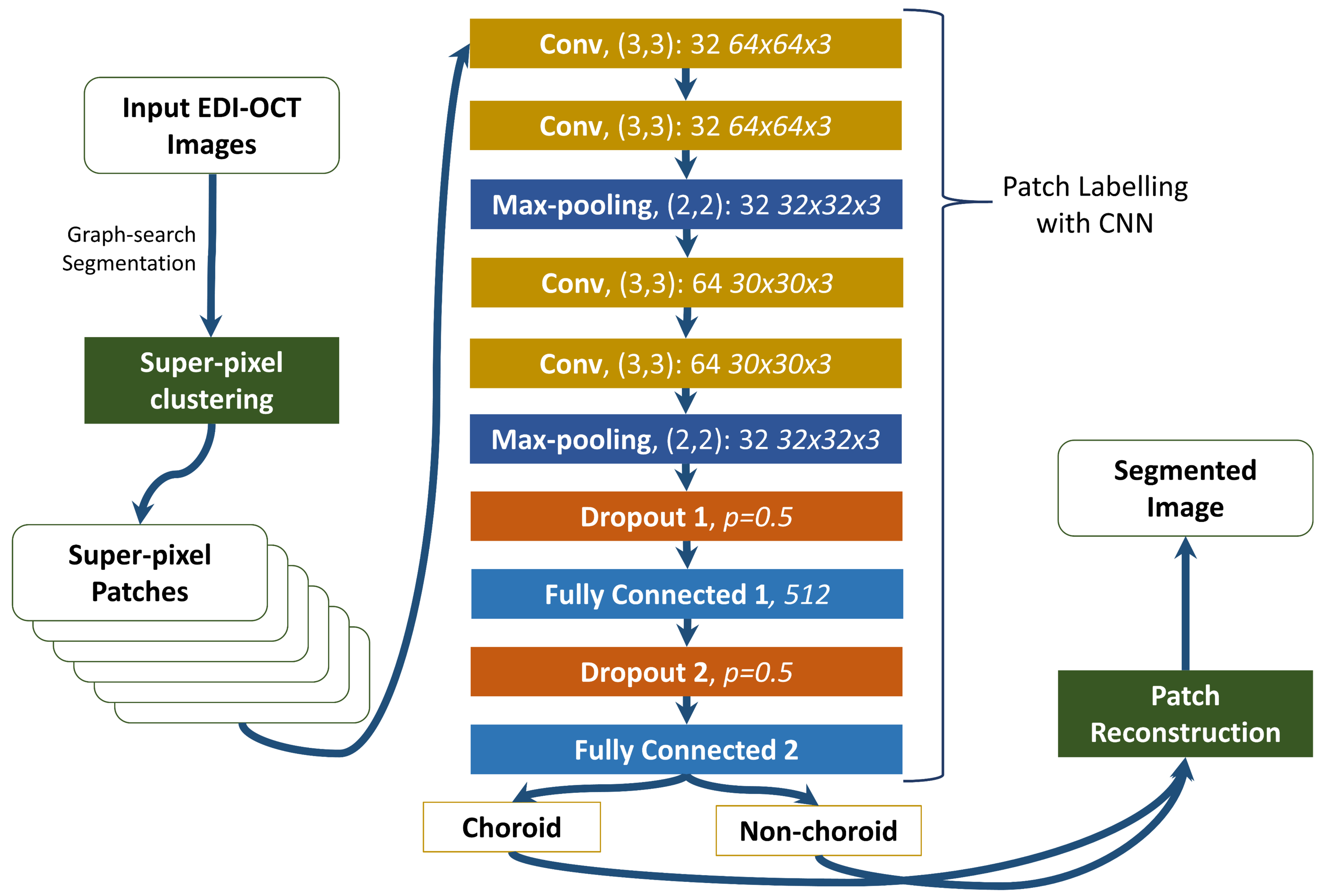
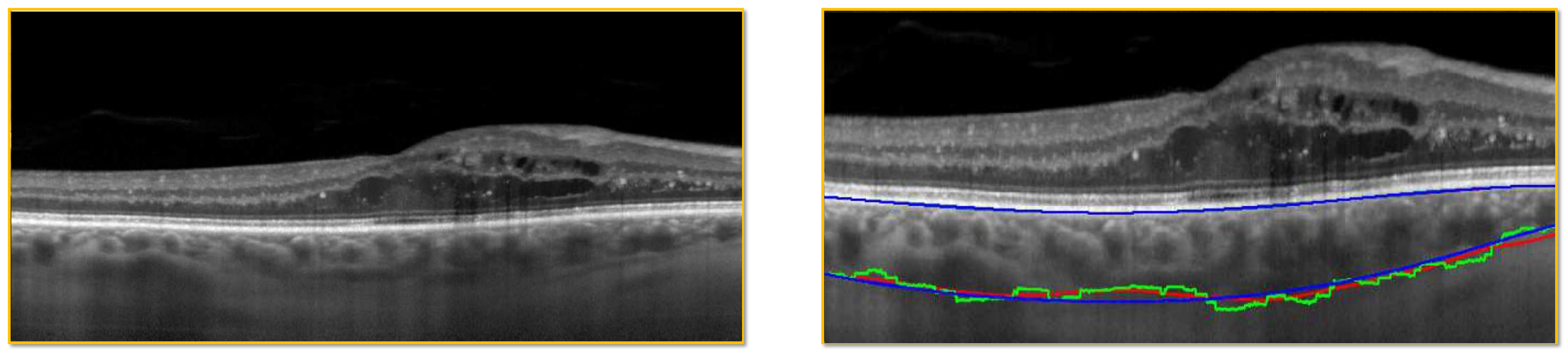


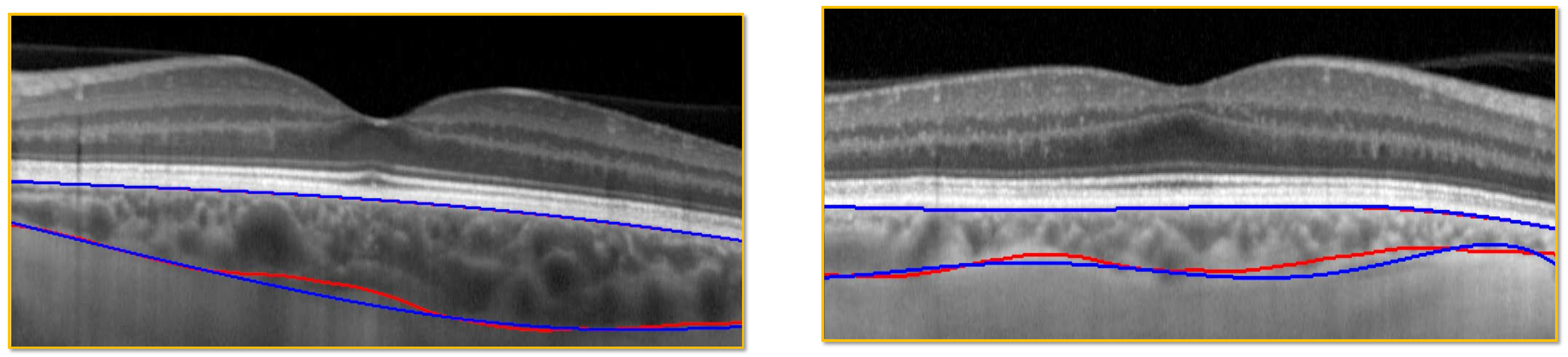
Figure 2: Flow chart of our overall approach. The input images are split into clusters, with which patches are extracted. These patches are then classified by our CNN so that the segmentation contours can be constructed.

Results



(a) EDI-OCT Image | (b) Our result (red)

Figure 4: Example of segmenting the choroid in an EDI-OCT image (a) by our technique (b). The CNN result (green) is reconstructed and smoothed (red) to give a segmentation close to the expert's annotation (blue).



(a) Our result (red) vs expert (blue) | (b) Our result (red) vs expert (blue)

Figure 5: Two examples of choroid segmentation using our method. In both images, the red contour represents segmentation by our technique and the blue contour was drawn by an expert grader. In both cases, our result is close to the expert's but our method is very fast and requires no human intervention.

Results (cont.)

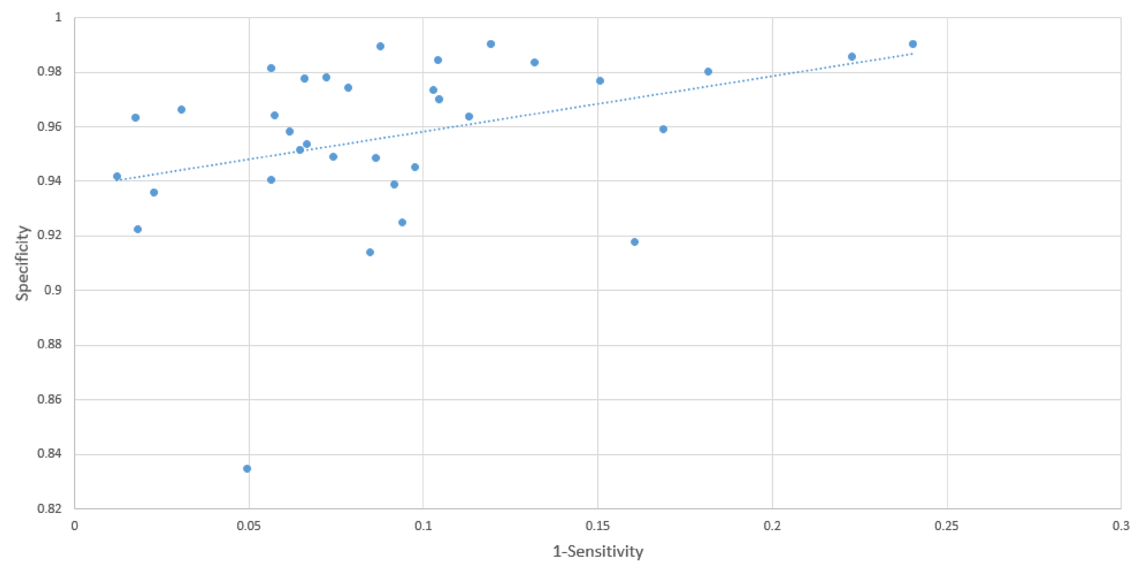


Figure 6: Plot of specificity against 1-specificity

Agreement	Mean±SD	Maximum	Minimum
Accuracy	0.942±0.03	0.977	0.863
DC	0.896±0.04	0.948	0.752
Sensitivity	0.907±0.06	0.988	0.780
Specificity	0.957±0.03	0.990	0.835

Table 1: Accuracy, Dice Coefficient (DC), Sensitivity and Specificity results of 34 randomly selected EDI OCT testing images.

- Patch size 65x65 was determined to be the best performing of the sizes tested.
- The mean accuracy of our overall segmentation technique was 0.942±0.027 with range: 0.863 – 0.977.
- The mean dice coefficient was 0.896±0.043 with range 0.752 – 0.948.
- Our fully-automatic segmentation technique was easy to use with no interaction required.

Conclusions

- Our results have demonstrated the ability of our method to accurately segment the choroid, almost in real time and more accurately than previous techniques.
- This can pave the way for more accurate diagnosis and improved management of a range of chorioretinal diseases.

References

1. Chung S.E., et al. , Ophthalmology, 2011.
2. Kim Y.T., et al., Eye, 2011
3. Spaide R.F., et al. Am J Ophthalmol, 2008

Acknowledgements

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